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A CRITIQUE OF THE DOD MATERIEL DISTRIBUTION STUDY.(U)
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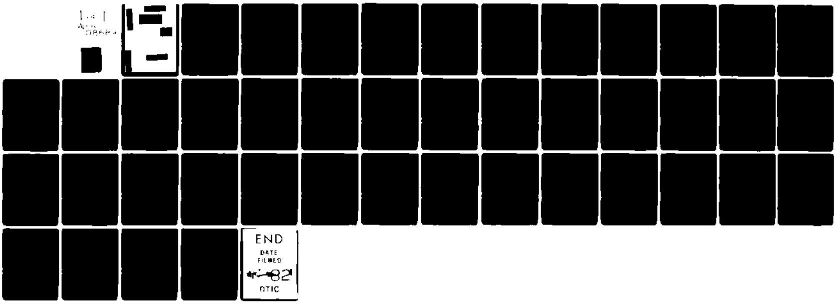

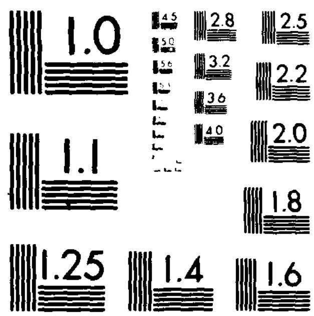

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A CRITIQUE OF THE DOD MATERIEL

DISTRIBUTION STUDY

March 1979

Prepared for Logistics Management Institute

by:

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PREFACE

In August 1978, the Logistics Management Institute was tasked by the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics) to sponsor an independent review of the DoD Materiel Distribution System (DoDMDS) Study. Under that tasking, consultants from the University of Pennsylvania and Cornell University were retained to conduct a technical assessment of the modeling assumptions and methodology employed. The consultants' findings are presented in this report.

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I. INTRODUCTION AND SUMMARY

This critique of the DoD Materiel Distribution System (DoDMDS) Study is based on both the 10-volume DoDMDS Report[1] and the 2-volume Appraisal produced by the Defense Logistics Analysis Office.[2] The DLAO report discusses in detail many aspects of how the study was conducted and focuses mainly on assumptions about the data. This report, which is the result of a much smaller effort, is addressed more to how the primary tools--a mixed integer linear programming package and a dynamic simulation--were employed.

The body of the report is divided into two major chapters. Chapter II is a critique of the macroanalysis, and Chapter III is a critique of the use of the simulation package. The following major points are made:

1. The estimated annual operating costs of the materiel distribution system recommended in the DoDMDS Study were seriously understated due to errors in transportation and fixed cost calculations.

2. The errors in transporation costs were caused by the clustering of depots, which was unnecessary. The errors in fixed costs arose because the DoDMDS study group inadequately considered the impact of increased workload on depot fixed costs.

3. A hypothetical system can be constructed from the DoDMDS data that has no depot closures and nearly the same costs as the recommended system.

4. The Technical Report asserts that the mathematical programming package used for the macroanalysis was the most sophisticated and comprehensive available. However, this is irrelevant since none of the special features of the package were used.

5. The simulation model was an appropriate tool for testing the dynamic performance of the recommended depot system. However, it was not

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[1] Materiel Distribution System Study, 1 July 1978. Hereafter referred to as the Technical Report.

[2] An Appraisal of the Joint Logistics Commanders' DoD Materiel Distribution System (DoDMDS) Study, Defense Logistics Analysis Office, August 1978. Hereafter referred to as the DLAO Report.

used effectively because many of the assumptions originally made for the macroanalysis were unnecessarily carried over into the dynamic analysis. These assumptions include: a high degree of commodity aggregation, clustering of depots, handling of capacities, and treatment of variable costs.

6. The DoDMDS Study was deficient in not considering inventory stockage policies and the requirement for new data processing systems implicit in the recommended system. Both are important determinants of system effectiveness and responsiveness.

The key question addressed in this study was: Do the results of the DoDMDS Study establish a firm basis for action by the Secretary of Defense? On the basis of both our critique and the DLAO Report, we believe that a conclusive case has not been made for the claimed savings. The inappropriate use of the modeling tools, the ill advised and unnecessary over simplification, and the omission of significant cost considerations all contribute to this conclusion.

II. CRITIQUE OF THE MACROANALYSIS

INTRODUCTION

This chapter concerns the macroanalysis phase of the DoDMDS Study, which was conducted using a mixed integer linear program (MILP) model. The critique is not intended to be comprehensive, since a thorough and extensive review has already been given in the DLAO Report. Rather, our focus is on certain aspects of the study that have either not been previously mentioned or deserve additional attention.

The major recommendation of the DoDMDS Study is a proposal for a new materiel distribution system in which a number of depots are closed and for which an annual savings of approximately $100 million is claimed. We demonstrate below that this claimed annual savings is overestimated by at least $28.4 million. Of course, savings may be reduced still further because of the many faulty assumptions and conclusions identified in the DLAO Report.

We also show that corrected annual costs for the proposed system would be no lower than the estimated annual costs for a system in which no depots are closed.

The final section of this chapter contains a critique of the DoDMDS Study methodology. The Technical Report makes much of the complexity of the problem addressed, and the power of the Geoffrion-Graves optimization code used. We agree that this package is a powerful and flexible tool, but it was applied to an extremely simple model which could not effectively utilize the many options for problem complexity contained in the package.

ANALYSIS OF COST ESTIMATES FOR THE REFINED SYSTEM

Table II-1 is a cost summary of three systems considered in the DoDMDS Study. The Base-Line System is the current materiel distribution system. The Objective System is the optimal solution to a particular 15-cluster model analyzed in the study. The Refined System is obtained from the Objective System by reassigning certain customers to correct various infeasibilities, which occur mainly because product aggregation does not consider certain constraints actually required in the Objective System. The difference in cost between the Objective and Refined Systems is due to the increase in transportation costs caused by the customer reassignments.

The Refined System is reported in the Executive Summary of the Technical Report as the new materiel distribution system. The difference in annual operating costs between the Base-Line and Refined Systems is approximately $100 million, and this is the savings the study claims will be realized by adoption of the Refined System.

TABLE II-1. COST SUMMARY

($ millions)

Cost Element	Baseline	Objective	Refined
Transportation	574.1	503.1	515.9
Depot Fixed/Variable	430.0	387.2	387.2
Total	1,004.4	890.3	903.1

However, this $100 million savings claim is inconsistent with statements made elsewhere in the Technical Report. We will use these statements and other data in the report to show that the estimated annual operating costs for

the Refined System should be increased to at least $931.5 million. It is important to emphasize that this increase would be justified even if all the assumptions and data in the report were accepted. Even greater increases in the annual cost estimate could occur if the assumptions or data were found to be unacceptable.

The cost increase is accounted for by two changes, one in transportation costs and the other in fixed costs.

Transportation Costs

The Technical Report states that transportation costs for the Objective and Refined Systems are understated by $15 to $20 million (Vol. II, p. 181). Yet this extra $15 to $20 million is not subtracted from any savings claims made in the Executive Summary.

The error in transportation costs occurs because of clustering. When depots are clustered, the transportation cost from any customer to a depot within a cluster is taken as the average over all depots in the cluster. Further, if a customer has zero transportation cost to any depot in the cluster, then its transportation cost to the entire cluster is taken as zero. This last assumption is not even approximately valid and would definitely cause an error in transportation costs.

It is also questionable whether the estimate of $15 to $20 million for the error in transportation costs is correct. The Technical Report gives absolutely no justification for this estimate, or, in fact, any indication of how the estimate was obtained. Hence, one must assume that the estimate is very rough and that the actual error could well be even higher.

It is important to note that there is absolutely no need to guess at the correct value for transportation costs. An accurate figure can easily be obtained by making a single run of the model in which there is no clustering,

that is, in which each of the 34 depots is treated discretely. In this run, the depots recommended for closure would be locked closed, and all the other depots would be locked open. The depots to be locked closed would be all depots in closed clusters and the four depots recommended for closure in the Northern California, Utah, and Virginia clusters (see Executive Summary pp. 37-38).

Such a run could also be used to impose capacity constraints at each depot and thereby obtain a more accurate assessment of the effect of capacity restrictions. This run would be similar to run number 231, in which the cost effect of customer reassignments made in going from the Objective to the Refined System was determined by locking these reassignments into the model.

Fixed Costs

Depot operating costs were broken into fixed and variable components. Variable costs are irrelevant to the comparison being made here, because the variable cost per unit for a given product is assumed to be equal over all depots. This means that variable depot costs will be a constant for any materiel distribution system. Hence, the question of how many and which depots to have reduces to a trade-off between fixed depot costs and variable transportation costs.

The term "fixed cost" is somewhat misleading. Included in fixed costs were expenses for items like upper level echelons of supervision, clerical management, data processing support, motor pool, building maintenance, civilian personnel office, and administrative services. Although it is true that these expenses are fixed in the short run, in the long run they would have to increase if the workload at a depot were substantially increased. This fact was clearly recognized by the study group, and the

Technical Report makes several references to fixed costs' varying with work volume. The most comprehensive statement is the following:

> An assumption was made that historical depot fixed costs were applicable only within a limited range of historical throughput. For optimization analysis a 25 percent increase in throughput measured in weighted throughput was assumed as the range for which the historic fixed cost was relevant. In order to predict the effect of a larger increase in workload on fixed costs, a relationship between weighted throughput and depot fixed costs was developed. This appendix explains the methodology used to develop an equation for predicting estimated fixed costs as a result of increases in weighted throughput exceeding 25 percent. (Vol. III, Bk. 8, App. F, Sec. 5, p. F-5.1)

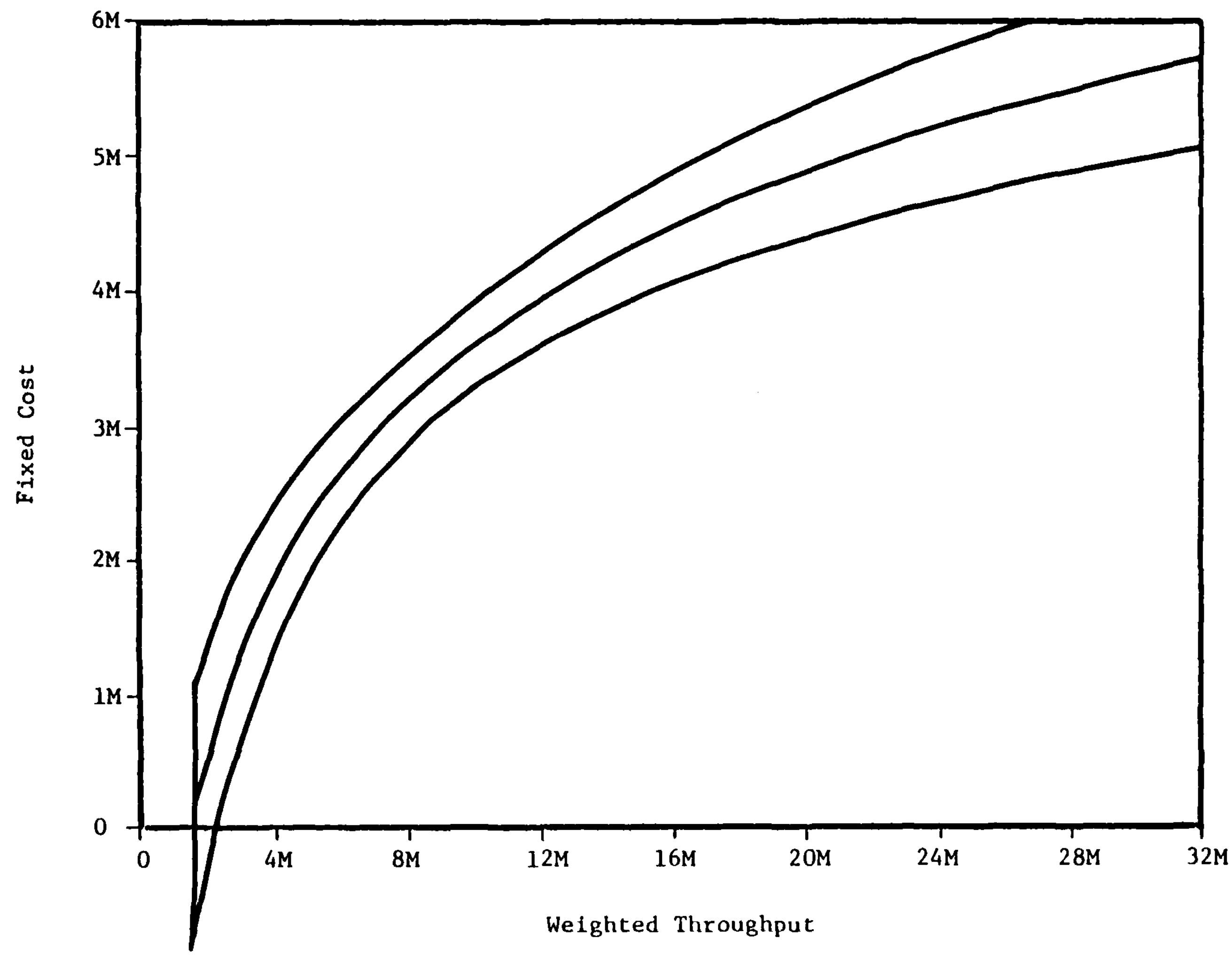
A formula relating fixed costs to weighted throughput was then derived by means of regression analysis:

$$\text{Fixed Cost (\$M)} = -13.27877 + 1.83289 \ln (\text{Weighted-Throughput in 000})$$

Figure II-1 is a graph of this formula, taken from the same appendix (p. F-5.6). The graph of the formula is the middle line of the three curves shown.

The fact that fixed costs should vary with weighted throughput was totally ignored in the analysis that led to the Refined System. The model used to derive the Objective and Refined Systems contained nothing that allowed fixed costs to vary with volume. Moreover, essentially no attempts were made to adjust fixed costs once the Refined System had been obtained, despite a number of depot clusters having weighted throughput more than 25 percent greater than the Base-Line throughput. There is one small exception to this statement. On pages 38 and 39 of the Executive Summary, the following statements appeared: "It was estimated that fixed costs for Oklahoma City would increase by $2.4 million" and "This potential increase in fixed costs [for the Georgia/Florida cluster] was estimated at $3.1 million." However, these adjustments in fixed costs were not included in the final tally of

FIGURE II-1. RELATIONSHIP BETWEEN FIXED COST AND WEIGHTED THROUGHPUT



operating expenses for the Refined System. Neither were they subtracted from the claimed savings for the Refined System, as they should have been.

We have used the formula for fixed costs that was derived in Appendix F to compute adjustments in fixed costs. These adjustments would be expected to result from the changes in weighted throughput in the Refined and Objective Systems. These changes are displayed in Table II-2.

TABLE II-2. FIXED COST CORRECTIONS - OBJECTIVE SYSTEM

Clusters	WTP (Millions)		Fixed Costs ($ Millions)		
				Objective	
	Baseline	Objective	Baseline	Claimed	Corrected
1. No. California	56.5	58.8	24.3	16.3	17.8
2. So. California	12.0	22.5	7.7	7.7	11.2
3. Virginia	31.6	47.4	14.2	14.2	12.1
4. Pennsylvania	50.7	53.2	14.8	14.8	-
5. Utah	37.4	17.6	14.8	4.9	4.9
6. Lexington	3.0	0	1.6	0	-
7. Anniston	9.1	23.6	2.2	2.2	3.9
8. Georgia/Florida	14.5	21.5	6.3	6.3	9.4
9. Texas	20.6	16.1	3.3	3.3	-
10. Red River	11.3	20.2	4.2	4.2	5.3
11. Pueblo	2.8	0	1.8	0	-
12. Pearl Harbor	.4	1.3	.5	.5	2.7
13. Memphis	21.0	0	7.1	0	-
14. Oklahoma City	19.6	27.4	2.9	2.9	5.3
15. Ohio	19.4	0	14.7	0	-
Total	309.9	309.9	120.4	77.3	90.7

The first two columns show the weighted throughput for the Base-Line and Objective Systems. The numbers for the Base-Line System were taken from the Technical Report, Vol. II, p. 180, Table 5-4. The weighted throughput for the Objective System was obtained by applying the percentage increases given in the same table to the Base-Line throughput.

The third column gives the fixed costs for the Base-Line System. The fourth column gives the fixed costs for the Objective System that were

claimed in the Technical Report. The data for columns three and four were taken from the Technical Report, Vol. II, p. 181, Table 5-6.

The last column shows the corrected fixed costs obtained by taking account of throughput changes at each cluster. When no entry is made in this column, it means that the fixed cost claimed in the Technical Report is correct. This occurs for clusters number 6, 11, 13, and 15, because all depots in these clusters are closed. It also occurs for cluster number 4 because the increase in throughput at this cluster is less than 25 percent. The corrected fixed costs for clusters 8 (Georgia/Florida) and 14 (Oklahoma City) are obtained by adding in the estimated increases in fixed costs described in the statements from pp. 38-39 of the Executive Summary quoted above. All other corrected fixed costs are obtained by applying the fixed cost formula displayed above.

We will illustrate how this formula was used for cluster 7, Anniston. Referring to the first two columns of Table II-2, we note that the Base-Line weighted throughput at Anniston is 9.1 million. In the Objective System, the weighted throughput increases to 23.6 million. To estimate the effect that this increased throughput has on fixed costs at Anniston, we substitute 9,100 and 23,600 into the formula for fixed costs to compute fixed costs with the old and new volumes. Subtracting the old fixed costs from the new gives the increase in fixed costs. Specifically,

$$\begin{aligned}\text{Increase in Fixed Costs at Anniston} &= [-13.27877 + 1.83289 \ln (23600)] \\ &\quad - [-13.27877 + 1.83289 \ln (9100)] \\ &= 1.83289 [\ln (23600) - \ln (9100)] \\ &= 1.7467.\end{aligned}$$

This increase in fixed costs at Anniston is added to the current fixed cost of 2.2 million to obtain the corrected fixed cost of 3.9 million shown in the last column of Table II-2.

For clusters containing more than one depot, the analysis is complicated by the fact that the weighted throughput for each depot in the Base-Line and Objective Systems is unknown. This information does not appear to be given anywhere in the Technical Report or Appendices. For multiple depot clusters, we have simply assumed that the cluster weighted throughput for the Base-Line and Objective Systems is divided equally among the depots in the cluster. We believe that the effect of this assumption on our computations is minimal. In clusters where some depots were closed 1, 3, and 5), we conducted our analysis on the assumption that the specific depots closed would be those recommended for closure on pages 37 and 38 of the Executive Summary, i.e., SHAD, DDTC, DDOU, and DGSC. The corrected fixed cost was obtained by adding the estimated increase in fixed costs to the specific fixed cost for the depots remaining open as reported on pages 247, 256, and 259 of the Technical Report.

We will illustrate the computation of a corrected fixed cost in the case of a multi-depot cluster for cluster 1, Northern California. This cluster contains six depots, two of which (SHAD and DDTC) are closed in the Ojbective System. Table II-2 shows the Base-Line and Objective throughput for this cluster as 56.5 million and 58.8 million, respectively. Assuming that throughput is divided equally over all open depots in a cluster, Base-Line throughput for each depot would be 56.5 million/6 = 9.4167 million, and Objective throughput for each of the four depots that remain open would be 58.8 million/4 = 14.7 million. The increase in fixed costs for the four

depots whose weighted throughput increases from 9.4167 million to 14.7 million can be computed as before using the fixed cost formula. Specifically,

$$\begin{aligned} \text{Increase in Fixed Costs} &= 1.83289 \, [\ln (14700) - \ln (9417)] \\ &= 1.83289 \, [9.5956028 - 9.1503718] \\ &= 0.8162427. \end{aligned}$$

This is the increase for each of the four depots. Multiplying this by 4 and adding the current fixed cost of 3.2 + 1.9 + 1.7 = $14.5 million (numbers are taken from page 247 of the Technical Report) yields the corrected fixed cost of $17.8 million shown in the last column of Table II-2.

The effect of these corrections is to increase the fixed costs for the Objective System to $90.7 million, an increase of $13.4 million over the fixed costs claimed in the Technical Report. Total depot costs for the Objective System thus increased from $387.2 million to $400.6 million.

The customer reassignments made in going from the Objective to the Refined System will change the weighted throughput at some depots. However, these changes are not reported in the Technical Report. Moreover, they are not taken into account in the extensive sensitivity analysis that was conducted before the derivation of the Refined System. Therefore, we have assumed that the corrected fixed costs derived for the Objective System are valid also for the Refined System. This leads to the corrected cost summary shown in Table II-3 for the Refined System. As may be seen, the corrections for transportation and fixed costs, which are based totally on statements made in the Technical Report and Appendices, increase the cost estimate for the Refined System from $903.1 million to $931.5 - $936.5 million.

TABLE II-3. CORRECTED COST SUMMARY

($ Millions)

Cost Element	Baseline	Refined	
		Claimed	Corrected
Transportation	574.1	515.9	530.9-535.9
Depot Fixed/Variable	430.3	387.2	400.6
Total	1,004.3	903.1	931.5-936.5

Although the analysis we have conducted corrects the most glaring errors in the analysis of fixed costs, it is not presented as a substitute for the DoDMDS analysis. The structure of an optimal materiel distribution system depends critically on the way in which fixed costs vary with the volume of activity at a depot. This is a subtle point that was totally ignored by the study group.

To illustrate the importance of fixed costs, consider the evaluation of a hypothetical example using the fixed cost curve displayed from Appendix F. Imagine that we have two depots, each with a weighted throughput of 12 million. In this case, using the curve from Appendix F, we can see that the fixed cost of each depot is $3.94 million. What would be the reduction in fixed costs if one of these depots were closed and its volume assumed by the other depot? Clearly, it would not be $3.94 million, as assumed by the study group. We would now have a single depot with a weighted throughput of $24 million, so its fixed cost would have increased to $5.21 million. Hence, the savings in fixed costs is not $3.94 million, but $7.87 million - $5.21 million = $2.66 million.

It is important to realize that the amount of savings in fixed costs depends crucially on the shape of the curve relating fixed costs to processing

volume. The fact that there is any savings at all in the hypothetical example we just discussed is due to the concavity of the curve in Appendix F. If this curve were linear, there would be absolutely no savings in fixed costs in combining two small depots into one large depot. On the other hand, if the curve flattened out more quickly, there might be even greater savings. Because this fixed cost relationship has such a strong effect, the study group should have done two things: (1) invested greater effort in determining the shape of this curve at each depot and (2) incorporated this more complicated cost structure into their optimization model. This could easily have been done with the Geoffrion-Graves optimization package, as will be shown in a later section.

With respect to the first point, we note that the curve in Appendix F was obtained in a single regression run in which a logarithmic relationship between fixed costs and weighted throughput was assumed. The correlation coefficient, r^2, for this run was 0.74. We do not regard this as proof that the correct relationship is logarithmic, since no other relationships were tried, and 0.74 is not a particularly large r^2. Appendix F contains the following comment on this regression run.

> As expected the logarithmic curve <u>produced</u> in this analysis shows a declining rate of increase from small to large depots, <u>supporting</u> the intuitive observation that there are economies of scale associated with depot fixed costs. (emphasis added)

This statement is patently absurd. The logarithmic curve was not "produced," it was assumed, and hence it does not "support" anything!

<u>COMPARISON OF THE REFINED AND REALIGNED SYSTEMS</u>

The previous section justified a substantial increase in the estimated costs for the Refined System. Nonethless, the estimated costs for that system are still less than for the Base-Line, so one might conclude that the proposed Refined System should be implemented. In this section we will invalidate that

conclusion by exhibiting a system that does essentially as well cost-wise as the Refined System and requires no depot closures. This system, called the Realigned System, was obtained by running the model with all depots locked open; the only difference between it and the Base-Line is that some customers have been reassigned so as to reduce transportation costs.

The Realigned System was obtained in model run number 179 and is described on pp. 179-180 of the Technical Report. According to this run, transportation costs in the Realigned System were reduced by $75 million over the Base-Line System. It was concluded that the costs of the Realigned System should thus be $75 million less than the Base-Line System. This is not completely correct, because the weighted throughput at the depot clusters is different in the Realigned and Base-Line Systems, and the difference should be expected to affect fixed costs for the reasons discussed at length in the previous section.

To estimate the effect of the differences in weighted throughput on fixed costs, an analysis was conducted for the Realigned System, based on the results in Appendix F. The results of this analysis are reported in Table II-4, which is analogous to Table II-2. Corrected fixed costs shown in the last column of this table were computed in the same way as the corrected fixed costs in Table II-2. The data in Table II-4 were used to produce the cost comparison between the Refined and Realigned Systems shown in Table II-5.

The $15 to $20 million understatement of transportation costs that occurred as a result of clustering for the Objective and Refined Systems should not be present for the Realigned System, because all depots were open in this system. In fact, the use of an average transportation cost, would, if anything, overestimate transportation costs in the Realigned System. This is because customers would be assigned to the closest depot in a cluster, while

TABLE II-4. FIXED COST CORRECTIONS - REALIGNED SYSTEM

Clusters	WTP (Millions)		Fixed Costs ($ Millions)		
				Objective	
	Baseline	Objective	Baseline	Claimed	Corrected
1. No. California	56.5	58.8	24.3	24.3	-
2. So. California	12.0	22.6	7.7	7.7	11.2
3. Virginia	31.6	46.8	14.2	14.2	17.5
4. Pennsylvania	50.7	50.7	14.8	14.8	-
5. Utah	37.4	16.8	14.8	14.8	10.4
6. Lexington	3.0	4.1	1.6	1.6	2.2
7. Anniston	9.1	14.7	2.2	2.2	3.1
8. Georgia/Florida	14.5	21.0	6.3	6.3	9.4
9. Texas	20.6	16.1	3.3	3.3	2.4
10. Red River	11.3	16.7	4.2	4.2	4.9
11. Pueblo	2.8	3.9	1.8	1.8	2.4
12. Pearl Harbor	.4	1.3	.5	.5	2.7
13. Memphis	21.0	8.0	7.1	7.1	5.3
14. Oklahoma City	19.6	23.5	2.9	2.9	5.3
15. Ohio	19.4	5.0	14.7	14.7	12.2
Total	309.9	309.9	120.4	120.4	128.1

TABLE II-5. CORRECTED COST SUMMARY

Refined vs. Realigned Systems

($ Millions)

Cost Element	Baseline	Refined		Realigned	
		Claimed	Corrected	Claimed	Corrected
Transportation	574.1	515.9	530.9-535.9	499.1	499.1
Depot Fixed/Variable	430.3	387.2	400.6	430.3	438.0
Total	1,004.1	903.1	931.5-936.5	929.0	937.1

the clustering model used to evaluate the Realigned System would charge them the generally higher average transportation cost to the cluster.

We note that the annual estimated operating cost for the Realigned System is only slightly higher than for the Refined System: $937.1 million versus $931.5 to $936.5 million. Surely the possibility of obtaining this small reduction does not warrant the significant one-time investment and disruption involved in closing the depots that would be eliminated in the Refined System.

If the Realigned System were adopted, it might be possible to still reduce fixed costs without closing any depots. This could be accomplished by closing some buildings at those depots with multi-facility operations. There are a number of statements in the study report that support the feasibility of such partial closings. First of all, there are several references to the current system as having excess processing capacity; for example, "the DoDMDS had excess processing capacity in the base period." (Executive Summary, p. 16) Secondly, on page 88 of the Technical Report it is stated that "all of the DoDMDS installations include multiple building operations." As one advantage of this, "buildings can be closed during periods of reduced operations." It is further noted on page 88 that "over 8% of the DoDMDS buildings assigned a materiel storage function exceed their economic life." All of these statements suggest that fixed costs could be reduced by selectively closing or mothballing some buildings at some depots, possibly older buildings in substandard condition. This is a viable option to closing an entire depot, and it was not considered in the DoDMDS study report.

REVIEW OF ANALYTICAL METHODS

The above sections were a critique of the principal results of the DoDMDS Study. In this section we consider the quality of the analytical methods used to obtain those results.

Much of the Technical Report suggests that the analysis conducted was sophisticated and state-of-the-art. The difficulty of the problem is stressed; consider the statement: "Careful consideration of the above suggested a monumental combinatorial problem: there were literally millions of possible combinations of depot locations and sizes, stock location alternatives, customer assignments, supplier assignments, and materiel flows." (p. 125) Furthermore, the study group selected a powerful location analysis computer package: "All of the authorities contacted converged on the Multi-Commodity Distribution System Optimizer, developed by Professors Arthur M. Geoffrion and Glenn W. Graves, both of the Western Management Science Institute, UCLA, and available through their private consulting firm, Optimal Distribution System (ODS), as superior to any other known software package." (Vol. III, Bk. 7, App. D5, p. 2.5)

Despite these indications to the contrary, the analysis actually conducted was severely lacking in several respects. Although the problem studied is surely complicated, the mathematical model of the problem that was created was simplistic and did not use any of the special features in the Geoffrion-Graves optimization package that differentiate it from simpler location analysis tools.

To justify this assertion, we require a yardstick for measuring location models and analyses. The yardstick that we will use is taken from the paper "A Guide to Computer-Assisted Methods for Distribution Systems Planning" by Arthur M. Geoffrion.[1] In a section entitled "Important Problem Features To Be Modelled," Geoffrion writes:

> A distribution planning model is a comprehensive collection of precise statements and assumptions about the system which describes it in sufficient detail that this formalized representation can be

[1] Sloan Management Review, Winter 1975.

useful for answering the questions posed at the outset of this article. The art of designing an effective computer model is the art of compromising between degree of detail on the one hand and economy of use on the other. Essential features of the real system must be reflected in sufficient detail to assure that the model will yield valid conclusions and earn the active acceptance of management. But the level of detail should not be so great that the model's data requirements are unreasonably large, or that no available computational technique can solve it at reasonable expense.

Over the years there has been a gradual shift toward a greater permissible level of detail. This is due to the increased availability of computer-resident data sources and steady progress in computational techniques. In most cases it is no longer necessary to settle for highly simplified models that omit some of the most salient features of a firm's distribution system. Such oversimplification has been responsible for a high proportion of the past failures of distribution planning models in terms of their actual decision-making impact. Management will not implement conclusions based on an oversimplified model. (emphasis added)

The following problem features are common to many if not most real applications. Often they have been ignored or dealt with only approximately in an ad hoc fashion in the earlier models and even in many models in use today. Experience and common sense teaches, however, that these features should be incorporated directly in the model of any distribution system to which they apply.

Geoffrion goes on to list seven essential problem features:

1. Multiple Products

2. Two Stages of Distribution: Plants/Warehouses/Customers

3. Capacities for Plants and Size Limits for Warehouses

4. Warehouse Economies of Scale and Fixed Charges

5. Each Customer Serviced by a Single Warehouse

6. Shipments to Customers: Preserve the Identify of Originating Plants

7. Various Desired Constraints on Distribution System Configuration

A natural question to ask is "How does the DoDMDS model stack up against these seven criteria?" The answer is "Only one of these seven features was satisfactorily and completely included in the DoDMDS model!"

Multiple Products

The included feature was number 1, multiple products. As we shall discuss below, other features were either omitted entirely (features 2, 3, 6, and 7) or implemented in an incomplete or incorrect fashion (features 4 and 5). It could be argued that these features were not included because they are not an important part of the problem being studied, but we believe that at least features 2, 3, 4, and 5 are vitally important and that failure to correctly include them seriously jeopardizes the model. Furthermore, even if these features were unessential, one would then be left with the question "Why employ a sophisticated and expensive tool like the Geoffrion-Graves optimization package, the principal advantage of which is its ability to deal with realistically complicated models?"

We will now discuss in detail features 2 through 7, which were not included in the DoDMDS model.

Two Stages of Distribution: Plants/Warehouses/Customers

In terms of the DoDMDS Study, plants are analogous to supply sources and warehouses to depots. What this feature suggests is that the optimization model should allow the possibility of optimizing flows of products from both the supply sources to the depots and from the depots to the customer. The possibility of optimizing the first set of flows was completely removed from the model by the study group's assumption about supply sources:

> The relative availability of any commodity group was established across all supply source regions (procurement) and all customers (non-procurement), based upon historical supply patterns. The resultant system-wide proportions remained fixed regardless of the changes made to the distribution system structure. Additionally, these proportions of supply availability applied to each depot, regardless of location. (Technical Report, Vol. II, p. 156)

We find the last sentence of this quote to be vague. However, the only logically consistent interpretation is the following. Let S_{ij} denote the amount of commodity i historically supplied by source j. Define

$$f_{ij} = S_{ij}/(\sum_j S_{ij})$$

where the summation on j is over all supply sources. Then the requirement seems to be that each depot k that is open receives a fraction f_{ij} of commodity i from supplier j. Let c^{in}_{ijk} denote the per unit inbound transportation costs for commodity i from supplier j to depot k. Then the total per unit inbound supply costs for commodity i at depot k is

$$\sum_j f_{ij} c^{in}_{ijk} .$$

This cost is a constant independent of any other decisions in the model. This constant can simply be added to the variable cost v_{ik} for processing commodity i through depot k. Any optimization at the supply level has thus been completely eliminated.

This assumption about supply sources is clearly false. This fact was recognized in the study report: "This was a most conservative representation which tended to overstate inbound transportation costs somewhat. However, analysis revealed the overstatement to be modest (less than 15% in the base line system)." (Technical Report, Vol. II, p. 157) In dollar terms, a 15 percent overstatement in Base-Line inbound transportation costs is \$36.4 million! This is over one-third of the amount of savings claimed for the Refined System. How can an amount this large be termed "modest"?

The rationale for imposing the restriction is stated thus:

> Left to its own devices, the optimization model would flow materiel to a depot from the closest suppliers. The implicit assumption necessarily made by the model is that the "micro-mix" of constituent NSN's for a given commodity group is stable for each supply source; that is, each supplier can provide the entire range of aggregated

> stock numbers. However, it was impossible to enforce such a restriction when the NSN's were being aggregated, as the resultant number of groupings would have been far too large. (emphasis added) (Technical Report, Vol. II, p. 157)

Yet, the Executive Summary asserts: "To conduct a study of these dimensions required an aggregation of its component parts. Large-scale studies have frequently been criticized for aggregating a problem out of existence and unwittingly biasing the results through the aggregation process." (Vol. I, p. 27) Isn't that exactly what is happening here?

Capacities for Plants and Size Limits for Warehouses

In the DoDMDS system, plants are synomomous with suppliers. The treatment of suppliers has already been discussed above.

With respect to size limits for warehouses (i.e., depot capacity constraints) the following excerpt from the Technical Report is relevant:

> Flexible capacities were implemented as follows. First, minimum and maximum weighted throughput limits were specified for each depot. Second, a per unit penalty charge was developed for each throughput limit. This penalty was assessed (in addition to the depot variable cost) against each unit of weighted throughput which exceeded the boundary. In other words, the model had the option to violate a capacity constraint, but it could do so only by paying an additional charge.
>
> In practice, DoDMDS analysis always set the lower throughput bound and its corresponding penalty rate to be a zero for each depot.
>
> Elastic depot capacities provide additional benefits in terms of solution quality. For example, it may be far less expensive to accept a small capacity violation at a given depot rather than open an additional facility. Should only rigid limits be available to the model, it would have no choice in such an instance but to open additional depots to obtain the needed capacity. For small violations this is an extensive and wasteful alternative, since only a small fraction of the capacity of the additional depot is required. Of course, as the violation, with its corresponding penalty charges, increases at the first depot, the opening of additional facilities becomes more economically viable. Such trade-off analyses are automatically performed by the model. (Vol. II, pp. 158-159)

This approach to capacity constraints is quite reasonable, and would indeed have allowed the model to perform "automatic trade-off analyses." Nevertheless, on page 171 of the Technical Report, we find the following statement:

> Finally, because the objective of the cluster analysis was to get at the natural location economics of the DoDMDS, the elastic capacity penalty factor was set at zero to permit any cluster to handle as much throughput as the model wanted to give it.

This statement applied to all runs performed in conjunction with cluster analysis: in other words all of the runs used to support the study group's recommendations. The assumption completely removes any depot capacity constraints from the model. We see no reason it would be required because one is using clustering; clusters of depots also have a finite capacity.

Warehouse Economies of Scale and Fixed Charges

We have already discussed the way in which fixed costs vary with weighted throughput volume. It would be useful at this point to refer back to Figure 5-1, App. F, Bk. 8, Vol. III. This behavior of fixed costs with respect to weighted throughput volume is what Geoffrion means by warehouse economies of scale. Had it been included, it would have allowed the fixed charges assessed by the model to vary with weighted throughput as indicated by the curve. As it was, only a single fixed charge was assessed for each depot, independent of weighted throughput volume. We have already discussed the difficulties that this creates in terms of underestimating the true costs of a particular configuration.

Furthermore, it would have been entirely feasible to include such a cost structure using the Geoffrion-Graves optimization package. The following excerpt from the Technical Report describes how to do this:

> If economies-of-scale or diseconomies-of-scale are substantial enough to require different fixed-plus-variable cost figures for different ranges within the throughput spectrum, the ability to

> impose throughput limits allows a standard trick for accomplishing this: simply introduce several possible versions of a given facility, each with its own throughput range and cost figures. (Vol. III, Bk. 7, App. D-5, p. 2.14)

Each Customer Serviced by a Single Warehouse

This means that each customer should receive logically related products from the same depot. It is handled in the optimization package by defining what are called bundles. The Technical Report describes bundles thus:

> A partition of commodities into one or more bundles, with the understanding that if a customer zone is assigned to a particular distribution center for a certain commodity in bundle X, then that customer zone must be assigned that distribution center for all commodities in bundle X; the commodity partition can be the same for every customer zone or it can be different for different customer zones. The bundling concept is designed to avoid split sourcing customers to the extent that this makes physical and economic sense. (Vol. III, Bk. 7, App. D-5, p. 2.16)

There are several indications that the bundling concept was misused. First of all, the same bundles were used for all customers, even though they differ by customer. Second, certain statements in the Technical Report suggest that bundling was used, not to impose logical constraints on product flows to customers, but as a device for further product aggregation.

For example, the following assertion is made on page 165: "Further, an upper limit of only 15,000 outbound link combinations greatly constrained the possible customer-depot-bundle combinations. For these initial 24 runs, only 13 bundles were defined to permit more customers to be linked to more depots from more bundles." The number of bundles used was increased from 21 to 24 and finally to 27, but the increase did not have a significant impact on the resulting system structure or cost. If "the bundling concept is designed to avoid split sourcing customers to the extent that this makes physical and economic sense," the bundles should not be defined to "permit more customers to be linked to more depots from more bundles."

Another indication of the bundles' being inadequately defined to impose logical constraints on product flows to customers may be found on page 215 of the Technical Report:

> Some least-cost links selected by the optimization model were not consistent with the overall support patterns of certain customers. Unless a compelling reason was known to keep the customer assigned to the least cost depot, the customer was reassigned to a nearby depot already providing the preponderence of its support for other commodities.

If bundles had been corrrectly used, these ad hoc assignments made after the model was run would not have been necessary.

Shipments to Customers: Preserve the Identity of Originating Plants

The feature for doing this is described in Vol. III, Bk. 7, App. D-5, p. 2.18. It is followed by the statement: *"This optimal feature was not used in the DoDMDS analysis."*

Various Desired Constraints on Distribution System Configuration

No mention of any additional constraints is made in any of the DoDMDS reports.

Thus, of the seven essential features listed by Geoffrion, only the first, multiple products, was satisfactorily present in the DoDMDS model. We might also mention that the multi-product aspect of the problem was itself not an essential complication. It could have been removed by the following trick described by Geoffrion:

> It is worth noting that all of the methods above, although designed for problems with but a single product, can also handle more than one product if a simple trick is used: namely, replicate each customer as many times as there are products to be distinguished and assign an appropriate product demand to each. This trick essentially converts a multiple product problem to an enlarged but equivalent single product problem.

Use of this trick would allow one to express the DoDMDS model as a simple or uncapacitated plant location problem. Geoffrion makes the following statement about this class of problems:

> The final and simplest class of problems drops the warehouse throughput limits, leaving our fourth problem feature as the only one treated exactly. A great many methods have been proposed.

He then lists four algorithms for the simple plant location problem that have appeared in the literature. These methods date back to 1966. Any of these algorithms would have been applicable to the DoDMDS model.

Furthermore, relative to uncapacitated plant-location problems solved in the literature, the DoDMDS model is fairly small. The basic model contained 34 possible depot locations. The study group felt compelled to cluster these locations to reduce the number of possible locations to 15. Cornuejols et al have recently presented an algorithm for this problem based on a dual-decomposition method.[3] This method is applied to about 20 problems, ranging in size from those with 30 potential facility locations to problems with 100 potential facility locations. Solution times for the 100-location problems on the IBM 370/168 ranged from 1.3 seconds to 7.2 seconds.

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[3] G. Cornuejols, M. L. Fisher, G. L. Nemhauser, "Location of Bank Accounts to Optimize Float: An Analytic Study of Exact and Approximate Algorithms," Management Science 8, April 1977.

III. CRITIQUE OF THE DYNAMIC ANALYSIS

INTRODUCTION

This chapter analyzes the use of the Long Range Environmental Planning Simulator (LREPS), which was the second of the two mathematical models applied to the DoDMDS Study. LREPS was used to test the dynamic performance over time of the general system structures suggested by the MILP and described in the previous chapter.

Our review of LREPS indicates that it was capable of contributing significantly to the study. However, some of the modelling assumptions made were insufficiently justified; inventory control and maintenance functions were ignored; and there was a conspicuous lack of documentation. Hence, the simulation phase of the study was not as effective as it could have been.

USE OF THE LREPS MODEL

LREPS is a large-scale, event-oriented simulation program. It includes many important aspects of a materiel distribution system such as inventory control and transportation functions. The study group felt it had the characteristics necessary to adequately simulate the DoDMDS system.

Fixed and variable costs, by depot, for inventory, handling, and storage, are all allowed as input. An elaborate transportation pricing schedule based on mode, weight, and route, is allowed. Reports are generated on order cycle times by their components: communication times, depot order processing times, depot capacity delay times, and transit times. Customers can go to up to ten alternative depots for a particular product. The ability to represent inbound and outbound consolidation strategies occurs in two ways: (1) materiel flows

can be sent through intermediate nodes which consolidate or split bulk shipments, and (2) shipments may be delayed until a larger shipment is built.

After alterations were made for this particular study, the LREPS model could handle 498 supply sources and intermediate depot nodes, 500 products, and 9,989 customers. Additions to the LREPS model for this study included a mechanism for a shipping priority structure (to allow for the fact that all orders fall into one of three priority classes), a method to test depot capacities, and some special performance reports.

We agree with the study group that LREPS has virtually all of the desirable features a simulation model of a materiel distribution system should have. The many assumptions and the various aggregation processes needed to bring the MILP down to a manageable size made a dynamic, more detailed analysis of the proposed systems a necessity. Considering this, LREPS was capable of making significant contributions to the study.

The DoDMDS Study group wished to test the dynamic behavior of systems whose structures were suggested by the MILP. Each run of the MILP optimization program gave depot x product x customer links and transportation rates.

A comparison of actual historical data and simulation outputs for the same time periods with the same input data was made to validate the LREPS model. Unfortunately, there is no documentation of this comparison in the report. The report also says that two simulation data streams were compared to test the sensitivity of some of the major assumptions made during the model development stage, but again, there is no documentation.

In order to reduce the 27.4 million base year transactions to a reasonable number, they were first aggregated into 2.4 million orders (an order was defined to be all demand for all products for a customer in one

priority group from one depot for a day). This number was further reduced by the decision to run each simulation for 90 days instead of a year. No statistical validation was presented for this choice. Finally, the remaining 600,000 orders were grouped into several strata, and Neyman sampling was used to further reduce the number of orders actually handled by the program.

From the theory of Neyman sampling, the optimal allocation of the desired total sample size among the strata was derived. If, for example, it was decided that a stratum with 100 orders was to have 10 orders sampled from it, each of the 10 randomly chosen orders would have each of its factors (i.e., weight, cubic feet, dollar value, etc.) multiplied tenfold. Statistical analysis of the final aggregation of input data showed it to be (1) within 2 percent of the actual total demand, in terms of weight, lines, cubic feet, and dollars, and (2) within 10 percent for almost all weight and line totals by customer, by depot, by product, and by customer-depot combinations.

At the beginning of each simulated day, all orders were considered. Each order contained all of the necessary information (weight, cubic feet, dollar value, etc.) aggregated over the proper transactions as described previously. Each order was processed at each depot on a priority basis if it did not cause the depot capacity to be exceeded. Depot capacity was measured by both line items and weight in the model. If depot capacity was exceeded, the order was placed in one of three priority queues.

The order processing time was determined by priority group by depot. A 20-point probability distribution was used, based upon empirical data from the DoDMDS data base. The freight condition could be one of three states. Although usually determined by the mode and weight of the shipment, in this study it was assigned by the shipment's priority group only. For each freight condition, the transit time was randomly selected from the following three

choices: the mean, and the mean ±1 standard deviation. These were derived from historical data.

A simulation run as described was made using the base year data. The resulting run was called the baseline run, and it became the standard by which all alternatives were measured.

ANALYSIS OF ASSUMPTIONS

In this section, we take a closer look at some of the assumptions made to make the mathematical model of manageable size. The 3.7 million items managed by the Services and the Defense Logistics Agency (DLA) were aggregated into 72 general commodity groups, which were later aggregated into 27 commodity bundles. The 34 depots throughout the United States were aggregated into 15 depot clusters. The use of difficulty factors in standardizing the calculation of depot capacities is discussed. Finally we examine the consequences of using a standard variable shipping cost for a commodity across all depots.

Commodity Aggregation

In reducing the 3.7 million commodity types to 72 basic product groups, the emphasis was on preservation of management considerations, e.g., the way items are stored, handled, transported, and maintained. The further aggregation into 27 bundles was done by (1) similar handling and storage characteristics, and by (2) major commodity grouping (e.g., all automotive items).

This method does not yield the desired homogenity of items within a commodity group across depots. For example, what one depot considers small arms (wheeled vehicles and large antiaircraft, say), may not be the same as what is considered small arms at another depot (bayonets and 76mm guns, say). Also, the weights of all items within a group are assumed to take on the mean weight of all items in the group. Yet virtually none of the commodity groups formed had a normal distribution of the number of items at a

given weight. In fact, when item weight was plotted against the number of items at that weight in the commodity group, most of the resulting curves were bimodal or trimodal.

The concept of commodity bundles requires that the shipment of all items within a bundle to a customer be satisfied by one depot. Thus, there is no splitting of items within bundles. This requirement that a customer must receive any component of any aircraft engine, say, from the same depot, is quite restrictive and unrealistic.

The high level of aggregation also causes difficulties in assessing transportation costs and depot capacities. Transportation costs, which may be based on volume, weight, and special handling considerations, are difficult to assess, due to the wide range of values of these parameters found in any one group.

In the MILP, all depot facilities (with a few exceptions) were permitted to compete for all bundles from all customers. Thus, even though both the MILP and LREPS were capable of handling 500 commodity groups, the 3.7 million commodities were aggregated into only 27 bundles to keep the number of possible bundle x depot x customer combinations reasonable.

We think the 500 commodity capability should have been used to its capacity in both the MILP and LREPS. In order to do this, most of the bundle x depot x customer combinations could have been manually eliminated before a single computer run. For example, depots on the East Coast need not be considered for supplying a customer on the West Coast with an item that is stocked in four different California depots. Considering the amount of manual work done in the commodity aggregation process already, the manual reduction of bundle x depot x customer combinations to a manageable number using 500 bundles instead of 27, should have been feasible.

Clustering of Depots

The clustering of depots obscures the fixed costs of discrete depots since it masks individual depot fixed costs. It also obscures transportation costs. Local delivery is overstated, as any customer local to any depot in a depot cluster is now local to all depots in the cluster. Barstow and San Diego, for example, are 180 miles apart, yet in the same cluster.

The aggregation of 34 depots into 15 clusters offers no great computer savings, and it obscures costs. The consideration of individual depots could easily have been accomplished by the elimination of many bundle x depot x customer combinations prior to any computer run, as described in the previous subsection.

Calculation of Depot Capacities

In an attempt to standardize the calculation of depot capacities, much aggregation of data occurs, with the result that some key factors are ignored. In the MILP, depot capacity is measured in terms of throughput and storage. In the LREPS simulation runs, only throughput capacities are considered.

Recognizing that shipping 100 pounds (1 CWT) of steel does not cost the same (nor have the same shipping requirements) as shipping 100 pounds of feathers, a difficulty factor was derived for the MILP for each product group. This difficulty factor was calculated by a systemwide linear regression, and it converts CWT shipped into dollars. The weighted annual throughput capacity of a depot was defined to be the sum over all product groups of CWT of that group shipped in a year times the group's difficulty factor. Thus, the depot capacity is measured in dollars per year.

The ranges of values the difficulty factor assumes is from 1 to 342. Results are very sensitive to the accuracy of this number. Yet differences

in magnitudes appear not to be too defensible. According to this method of calculation, Barstow and Albany theoretically have enough capacity to service the entire Navy, while the Air Force is operating at less than 25 percent of capacity.

The use of dollars per year as the units which measure depot capacity seems inappropriate. It supposedly "incorporates a variety of workload parameters" through the use of the difficulty factor. However, due to the high level of aggregation of products, capacity factors, such as weights, volumes, and commodity mixes are lost in the derivation. Granted, the MILP does not permit the simultaneous expression of capacity in multiple variables, e.g., line items, cubic feet, and weight, all cannot be used simultaneously to measure capacity in the MILP. However, the difficulty factor should have been a function of both the depot being considered and of the commodity mix of its output.

The throughput capacity of a depot for the LREPS simulation was in terms of line items and CWT. These capacities were obtained as follows:

(1) The historical daily average of workload, by depot, was obtained by dividing the base year wholesale by the number of work days per year.

(2) The historical accelerated daily average depot workload was determined by increasing the historical daily average of depot workload calculated in (1) by 25 percent for all depots. This supposedly represents the level of throughput that could have been obtained without additional investment in labor, equipment or facilities, but with increased productivity via more efficient depot operation.

The calculation in (2) suggests that all depots are running at an identical 80 percent of maximum efficiency. Surely, some sort of depot-by-depot estimate of the possible increased productivity without a change in available resources would have been more reliable, and not too hard to derive. Also, the use of cubic feet as an additional measure of depot

capacity in the simulation model would seem to put a very small additional burden on it.

Depot storage capacities are not even considered in the simulation runs. This measure of capacity, as well as counts of on-hand inventory should have been important factors in the part of the study which supposedly analyzed the dynamic system performance over time.

Standard Variable Cost (SVC)

Depot variable costs are defined to be those directly related to materiel distribution workload. The Executive Summary (Vol. I, p. 22) states that "because of wide differences in depot size, management policies, mission, and other unique characteristics, a systemwide standard variable cost by DoDMDS product was developed...."

This should read "despite" and not "because of." Any item is assumed to have the same weight, cubic volume, and price data across all transactions and all depots. Yet variable costs account for more than two-thirds of total depot costs over the entire DoDMDS system. Consequently, masking these costs may seriously bias the outcome of the analysis. It is stated that the "conservative assumption (SVC) is employed to assure that the analysis does not overstate future savings." But the SVC assumption may do worse: it may affect the allocation of commodities to depots.

In defense of the use of SVCs, the study group says that "... managerial action can be taken, and investment in facilities and materials handling equipment (MHE) made, which would minimize differences in the depot variable cost rates...." This is not necessarily so! The investment in facilities and equipment depends on the amount of stock allotted to a depot, i.e., economies of scale. The SVC assumption completely ignores economy of scale.

Both the MILP and LREPS models are capable of handling individual variable costs by depot. Considering that there are only 34 depots (which were reduced to 15 clusters), this capability could easily have been used.

The critical point is that the SVC assumption is never justified anywhere in the Technical Report. It is merely stated that using it makes computations easier.

FACTORS IGNORED IN STUDY

Inventory Control

It is stated in the study that "complicated system trade-offs existed...and the relevant factors had to be addressed simultaneously if these interdependencies were to be correctly assessed." Yet it is assumed in both the MILP and LREPS models that any commodity demanded from a depot was always available, i.e., backorders never occurred. Clearly, inventory policies affect both response time and depot costs (fixed and variable). One of the primary purposes of the simulation runs was to measure customer response time, as the proposed systems operate dynamically over time. The measuring of response times without consideration of stockage levels is ludicrous.

A high percentage of items in the DoDMDS is inactive stock (the average number of turnovers per year for all items was 0.7 in the base year). Thus, low (or even zero) stock levels may be desirable for many commodities in the system. The unique assignment of depot to customer by commodity by the MILP is therefore not sufficient. Backorders are very common in the DoDMDS, which would make secondary and tertiary depot x customer x commodity assignments necessary. These secondary and tertiary assignments are vital if one is to obtain a realistic assessment of customer response times and transportation costs.

Another problem associated with both the lack of consideration of inventory policies and the clustering of depots is the allocation of safety stock. Calculation of safety stock desired at a depot for an item is sometimes done via a fixed square root formula. Thus, the summed safety stock allotted to each of a group of individual depots is not the same as the safety stock allotted to these depots considered as one cluster with total demand the sum of individual depot demands. Safety stock has a direct influence on the probability of backorders and also on customer response times. If the system safety stock is not increased, then more secondary and tertiary assignments will have to be made. In the long run, this increases pipeline times, which in turn increases pipeline stock, which in turn increases safety stock.

A key element of the DoDMDS Study was the desire to study the effect of sudden shifts in demand patterns (due to mobilization or wartime) on customer response times. Inventory policies and depot x customer x commodity assignments are an even greater factor in determining customer service levels in this case than under normal conditions.

The measure of pipeline inventory savings given with the proposed system structure is a function of transportation distances only, not of inventory policies. In reality, the expected delay due to lack of available stock is of significant magnitude relative to expected transportation time. The mean transportation time over all demands resulting from the proposed system is approximately three days. Yet backorders lasting three days or more are not at all uncommon in the actual system. Using mileage to estimate inventory savings is nonsense.

After analyzing the options deduced from all of the MILP and LREPS outputs, "guidelines" for materiel location are suggested. For each commodity group, the primary, secondary, and tertiary stocking locations are given.

This is too little, too late. Too little information is given: the inventory policies and parameter values are critical to both system costs and response times. It is also too late: stockage considerations should have been an integral part of at least the simulation. Inventory costs and fill rates could have been estimated using a METRIC-type model for recoverables and an Economic Order Quantity (EOQ) simulator for expendables.

Another crucial factor, depot capabilities for materiel flow/storage, is likewise ignored. The investment required to make a depot capable of accommodating different items is ignored. Special item characteristics such as weight, size, temperature, and their impact on storage facility requirements, are glossed over.

Management Information Systems

Intimately related to the study of inventory control and materials handling is the use of various management information systems. The limitations and capabilities of different management information systems are ignored in the DoDMDS Study. Though the cost of implementing certain proposed information systems was considered, their effects on performance were not.

The study group concluded that the smallest percentage cost increase over all areas of depot costs over the next ten years would be for computers, controllers, and intelligence acquisition devices. The most significant change in equipment technology and costs is expected to result from the "total systems approach" to warehouse design. Minicomputers and microprocessors will control conveyors and other pickers and keep inventory information, such as location inventory count. This will be a key determinant of order processing time, itself an important component of customers' service time. None of these factors is considered in the performance analysis of the proposed system structures.

In the event of a backorder (the existence of which was ignored) the speed with which an order can be levied on another location (if desired) depends on the communications links among the depots. Currently, a request upon an alternate depot due to a backorder in the Air Force's materiel distribution system takes an entire day. Furthermore, not all computers can "talk" to all other computers. Again, this is another factor affecting customers' service time.

Finally, there are different data processing systems and packages currently in use for existing Services which use the DoDMDS. No consideration is given to the consolidation of information processing systems that would be necessary if items of different Services were mixed at a location.

OTHER COMMENTS

There is no documentation of results which led to questionable conclusions such as the following:

- The number of commodity bundles, be it 21, 24, or 27, had no significant impact on the resulting system structure or cost, yet the 13-bundle structure was "far too restrictive."
- Discrimination among certain geographically close depots based on transportation costs was not realistic.

Each LREPS run of a proposed system structure simulated 90 days of DoDMDS operation. This seems like a very short amount of time considering that approximately 60 percent of all items experience no demand over a year. In one 90-day analysis, only 15 customers experienced a capacity delay, systemwide. Regardless of the fact that the number of delayed orders is low, due to the infinite availability of stock assumption, this seems like a very small number from which statistically valid conclusions are to be drawn.

Considering the importance of the role that should have been played by the LREPS simulation model, very little of the voluminous study report is

devoted to it. The page-after-page discussion of unimportant documentation shows a great lack of priorities.

CONCLUSION

The MILP phase of the DoDMDS Study was oriented towards depot output and transportation costs, not to issues such as inventory control and management. Given the enormous size of the materiel distribution system being modeled, the assumptions and some of the data aggregations made were necessary. The purpose of the MILP phase was just to suggest possible system structures.

The second phase, the LREPS simulation program, was supposed to dynamically test the systems proposed by the MILP over time. Given this objective, the simulation phase seems to have been misused.

The dynamic simulation's primary purpose was to measure the response capabilities of the distribution system. In particular, the order cycle time was defined to be the sum of communication, depot order processing, depot capacity delay, and transit times. As has been argued, the first three of these factors are directly dependent upon the sophistication of the data base, machinery and materials handling equipment, and on the specific inventory policies followed.

Although these factors can be ignored to reduce MILP to a manageable size, they could, and should, have been included in the simulation study. If they are ignored, the system cannot be said to have been dynamically analyzed. These factors are the ones that make a dynamic analysis necessary in the first place.

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This study reviews the methodology and assumptions employed in the DoD Materiel Distribution System (DoDMDS) Study. The purpose of the review was to determine if the results of the DoDMDS Study establish a firm basis for action by the Secretary of Defense. Study findings suggest that a conclusive case has not been made for the claimed savings. The inappropriate use of the modeling tools, the ill advised and unnecessary over simplification, and the omission of significant cost considerations all contribute to this conclusion.

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